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Failure analysis of composite bolted joints by an experimental and numerical approach

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Keywords : Composite material, bolted joint, finite element analysis

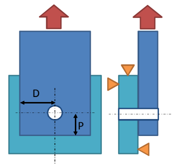
Introduction and context

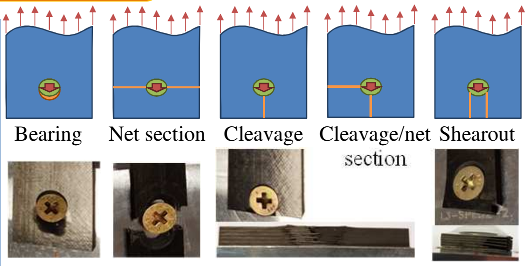
Source NIAR

Aircraft composite content (% weight)

- Few composite parts on Falcon aircrafts
- Need to master composite bolted joint behavior to satisfy performance and safety requirements

Studied design parameters
- End distance P
- Width 2D
- Load orientation



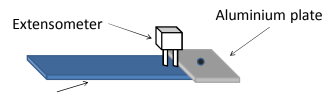


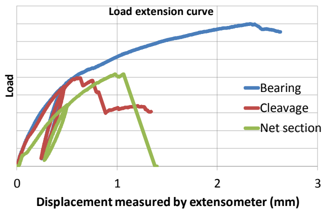
Failure modes of composite bolted joints

Objective: Define the necessary numerical modelling complexity for characterizing the effects of the design parameters on the failure modes of composite bolted joints

Experimental results and database analysis

Experimental settings for tests on supported single shear specimens

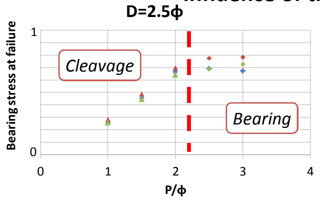


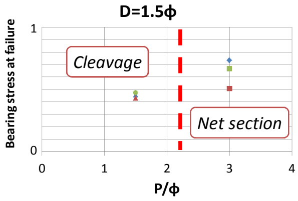


- Bearing stress at failure = $\frac{F_{max}}{t \times \phi}$

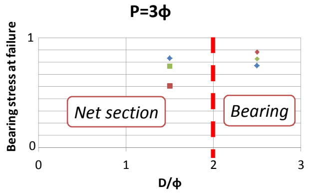
t : thickness ϕ : bolt diameter

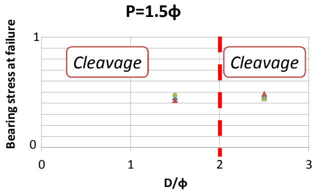
Influence of the end distance



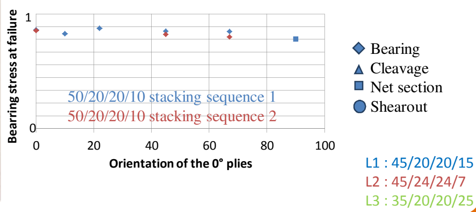


Influence of the width

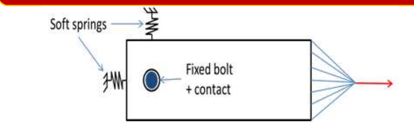


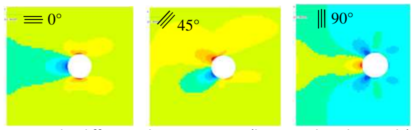


Influence of the load orientation



Two-dimensional finite element analysis





ϵ_{FF} in the different plies orientation (here P=3ϕ and D=2.5ϕ)

- FEM developed on Samcef Software (SIEMENS PLM Software)
- Linear elastic materials (for bolt and composite plate)
- Composite membrane elements

Criteria applied on each plies orientation:

- Maximal stress criterion (A)

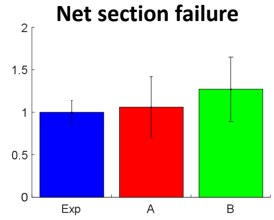
$$\frac{\sigma_{FF}}{\sigma_{FF}^{RT/C}}$$

- Modified Hashin's criteria (B)

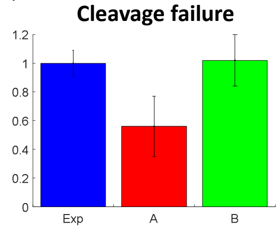
$$\left(\frac{\sigma_{11}}{\sigma_{11}^{RT/C}}\right)^2 + \left(\frac{\sigma_{12}}{\sigma_{12}^{RT/C}}\right)^2$$

- Net section (criteria on 0° plies)
- Cleavage (criteria on 90°)
- Bearing (criteria on 0° and ±45°)

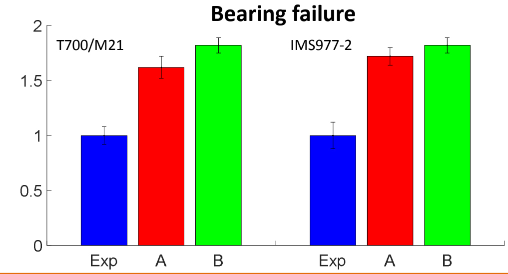
Net section failure



Cleavage failure



Bearing failure



Conclusions

Experimental database analysis:
Influence of the design parameters on failure modes and stresses:
- P is the most important parameter
- D and the load orientation have a lower influence

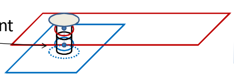
Numerical 2D model:
- Dispersions of criteria generally higher than experimental data
- Simple macroscopic criteria do not always predict failure
- Significant effect of shear

Perspectives

- Improving the FE modeling:

Secondary bending effect
- Out of plane effect modifying the stress field distribution

Fastener modelled with contact element on Samcef



Non linear behavior of composite material:
- Identify the role of each damage on the different failure modes

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